CREATING A QUIET WORK ENVIRONMENT IN SPACE

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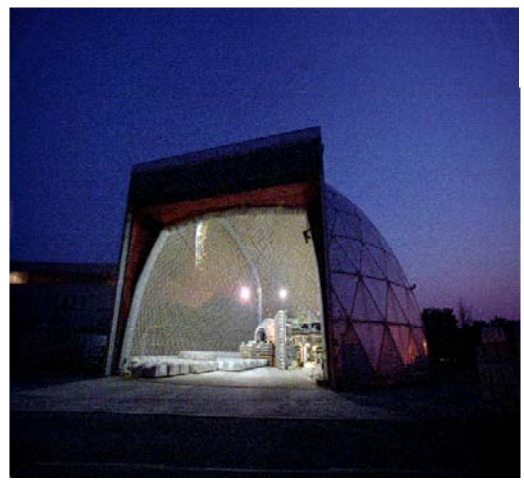
Thanks to aggressive low-noise design efforts on the part of engineers who are developing science experiment payloads for the International Space Station, astronauts studying the effects of microgravity conditions in space will be able to carry out their research in a quiet work environment, free from the risks of noise-induced hearing loss.

The International Space Station (ISS) is an on-orbit international laboratory that provides scientists, researchers and engineers from around the world with scientific research opportunities in microgravity. The ISS will provide researchers with the laboratory space, equipment and electrical power needed for safe, long- term investigations of how gravity affects physical phenomena such as fluid flow and combustion. Dedicated laboratory facilities on board the ISS will enable complex and challenging scientific investigations that require larger and longer experiments than are possible on the typical two-week space shuttle mission.

Science experiment payloads that will reside on the ISS are subject to acoustic noise emission requirements, which have been imposed by ISS to support hearing conservation, speech communication and safety goals as well as to prevent noise-induced vibrations that could adversely impact microgravity research data. These requirements include meeting a maximum sound pressure level criterion spectrum for acoustic emissions (the exact spectrum depends on the nature of the payload and its intended operational characteristics) as well as conducting sound power level testing in accordance with any of several published test standards.

Fluids and combustion research in space

The National Aeronautics and Space Administration (NASA) has designed and constructed an Acoustical Testing Laboratory (ATL) at its Glenn Research Center in Ohio, USA, to support the low-noise design of microgravity space flight hardware. The laboratory provides acoustic emissions testing and noise control services for a variety of customers, particularly for microgravity science experiment payloads that must meet ISS limits on acoustic noise emissions.



NASA's Aero-acoustic Propulsion Laboratory was the result of an earlier collaboration between NASA's Glenn Research Center and Eckel Industries.

In particular, the ATL was configured to be able to accommodate the specific demands of the Fluids and Combustion Facility (FCF), a multi-rack microgravity research facility being developed at the Glenn Research Center for the USA's Laboratory Module of the ISS. Although simple investigations of fluid interfaces and combustion processes can be addressed in small, contained experiments, more complex and challenging investigations require dedicated facilities to contain fluids and products of combustion in a controlled and safe environment. The FCF is being developed to accommodate the unique challenges of working with fluids and combustion processes in microgravity, as well as to provide services and capabilities comparable to those found in traditional Earth-based laboratories. This modular, multi-user, permanent microgravity science laboratory will make it possible for researchers on the ground, with the assistance of the astronauts in space, to schedule and perform studies of how fluids and flames behave in the absence of gravity.

The FCF will be capable of accommodating a minimum of ten experiment payloads per year over an expected ten-year life cycle.

Noise from the environmental control systems and other utility services in each of the FCF racks presents a considerable design challenge to the FCF development team. Noise emission, including the combined contributions of numerous noise sources (such as fans, cameras, gas handling systems and small motors) in each subrack payload, must be minimized in the context of a myriad of other design requirements that constrain the weight, volume, heat transfer and safety aspects of any noise control approaches or materials. The development of a successful noise control design for FCF that meets this great challenge will require a dedicated laboratory environment where repeatable and accurate noise measurements can be obtained throughout the life of the project.

The ATL will support this low-noise design process as well as the final acoustical verification testing for each of the FCF racks through the launch of the final rack, currently scheduled for 2005.

Demanding requirements for an acoustical laboratory

Although the Fluids and Combustion Facility project provided the primary motivation for the design and construction of the Acoustical Testing Laboratory at Glenn Research Center, this new NASA resource now provides *all* payload developers with the opportunity to actively integrate noise control strategies into their designs, right from the start. The ATL's state-of-the-art acoustical and operational capabilities are comparable to those of well known acoustical laboratories operated by commercial product manufacturers.

Unique performance and functionality criteria

The ATL was designed as a reconfigurable hemi/anechoic chamber to be able to comply with either the precision or engineering grade sound power standard, for typical experiment payloads up to a full rack in size (approximately 3ft. by 3ft. by 6ft. high.) Requirements for vibration isolation and very low background and self-noise levels were dictated by the need to acquire accurate and repeatable acoustic emission measurements on payload component that produced the lowest noise typically a small fan similar to those used in personal computers.

Some larger (full-rack-sized) ISS payloads, such as FCF, serve as permanent on-orbit test beds for experiments by providing common utilities and service connections to the ISS. These racks, and the subrack experiment payloads they host, usually require the operation of test support equipment in order to generate, under ground-based laboratory conditions, noise characteristics of on-orbit operations.

It is necessary to prevent noise produced by this support equipment, which can include high-noise items, such as chillers, pumps and power supplies, from contaminating acoustical measurements of the experiment itself. As a result, the support equipment must be located in a remote, noise-attenuating enclosure with the capability of running service hoses and cables between the test support enclosure and the test chamber to permit operation and control of the test article without any attendant acoustical leaks between the two rooms.

In the ATL, fiber-glass wedges with an overall treatment depth of 34in. provide an anechoic environment down to 100Hz.

Fast-tracked project schedule

Glenn Research Center's Acoustical Testing Laboratory was designed and constructed in less than one calendar year. From project inception in January 2000 until the grand opening and ribbon-cutting ceremony on 28 September, this fast-tracked project was an example of collaboration and cooperation among multiple teams of customers, construction contractors and equipment vendors.

At the outset of the project, NASA established an in-house design and construction management team to develop and manage the implementation of a unique, flexible laboratory design that would meet the specialized testing demands of microgravity space flight hardware. The NASA team worked closely with Eckel Industries of Massachusetts, USA, to expedite the successful completion of design *and* construction on an eight-month schedule.

No stranger to NASA's unique research capabilities, Eckel collaborated with the Glenn Research Center on the design of the world's only hemispherical anechoic chamber during the early 1990s. This unique facility, the Aeroacoustic Propulsion Laboratory, has provided a secure all-weather anechoic environment for a variety of acoustics research activities on scale model aircraft engine components for almost ten years. NASA and Eckel capitalized on their earlier success and established working relationship to jump-start the ATL project.

Responsive facility concept

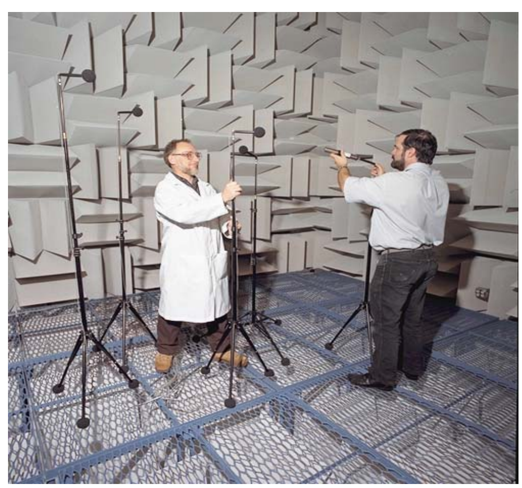
The ATL consists of a 100-Hz. hemi-anechoic test chamber with 27 ft. by 23ft. by 20ft. (height) outside dimensions (21ft. by 17ft. by 17ft. height interior working dimensions) and a separate sound-attenuating test support enclosure with outside dimensions of 23-ft. by 11-ft. by 12-ft. (h). The test chamber is vibration-isolated above 3 Hz., with removable floor wedges that allow the facility to be configured as either a hemi-anechoic or fully anechoic chamber. These characteristics, along with very low design background sound levels, enable the acquisition of accurate and repeatable acoustical measurements on test articles, up to a full ISS rack in size, that produce very little noise.

A separate sound-isolated control room doubles as a test support equipment enclosure, when testing articles that require remote connections to high-noise support equipment and services. Movable modular furnishings and strategically located utility sleeves facilitate reconfiguration of the enclosure so that data acquisition and test control functions may be easily relocated to an adjacent quiet area.

The ATL is sited, along with two other engineering verification facilities, inside a pre-engineered host building with dimensions of 50ft. by 150ft. by 35ft. (height). The host building provides the ATL with a conditioned exterior environment, overhead crane support and utility services such as chilled water and compressed air.

Reconfigurable hemi-anechoic test chamber

The test chamber is a modular pre-fabricated metal panel room, manufactured by Eckel Industries. Low background sound levels required for accurate acoustical measurements are afforded by 4in. thick wall panels with an internal septum, which provide noise reduction, rated at STC 54, between the host space and the test chamber. A silenced two-speed stand-alone ventilation system with 50 percent efficiency filtering provides conditioned air from the host space.



An expanded metal grating floor provides a walking surface above the wedges tips when the test chamber is configured as an anechoic room

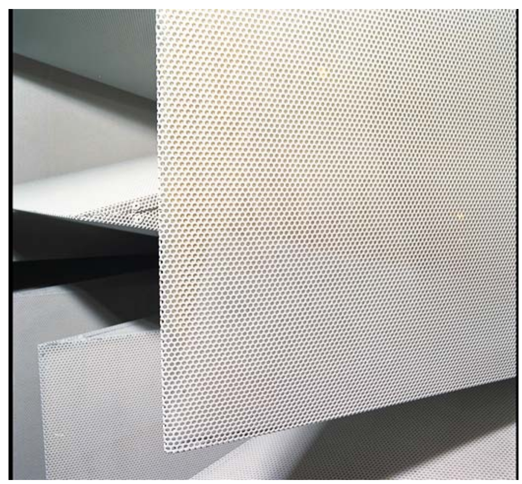
In the test chamber, fiberglass wedges with an overall treatment depth of 34in. provide an anechoic environment with a low frequency cutoff of 100 Hz. The Eckel Metallic Wedge (EMW) design incorporates a high-transparency perforated 22-gage metal facing with a 53 percent open area. A white acoustically transparent matting between the perforated facing and the fiberglass core of the wedge ensures positive fiber containment and uniform color. The chamber's EMW lining is modular with two 34in. peaks per wedge unit on a 2ft. by 2ft. base. The wedge units are factory finished in white enamel and were mounted to the walls and ceiling using Eckel's track mounting system.

An above-grade spring-isolated floor system affords vibration isolation above 3 Hz. for test articles with a maximum weight of 5,000Ib. Snubbers below the 6in. concrete slab allow an 8,000lb. forklift truck to maneuver test articles into position safely.

Constraints on the available space in the host building necessitated a smaller chamber than would have allowed full anechoic testing of the largest test articles according to the precision grade sound power standard. Therefore, the capability of configuring the chamber as either anechoic or hemi-anechoic was incorporated into the design to ensure that even the largest test articles would fall within the applicability of a published sound power standard. This is accomplished with removable floor wedges mounted in rolling carts. The chamber design was tailored to support reconfigurability by using horizontally split doors and a set of personnel access steps built into one of the floor wedge carts. Removable modular expanded-metal grating sections attached to each floor wedge cart provide a walking surface above the wedge tips.

To permit equipment access, the test chamber has one set of 9ft. by 10ft. high double doors that consist of two in-swinging wedge cage doors and two out-swinging sound doors. The cage doors incorporate curved radius wedges at their leading edges, which mate when the doors are closed, providing full depth of treatment coverage across the entire doorway. A removable 8ft. by 8ft. panel in the ceiling, which may be lifted by crane from above, also allows the crane to be used to place test articles within the test chamber. A single-leaf personnel door with absorber panels incorporated into the sound door functions as an emergency egress exit.

When the chamber is configured in the full anechoic mode, a set of portable steps is positioned at the exterior of the chamber during laboratory operations to permit entrance/egress between the walking surface above the floor wedges (approximately 46in. high) and grade level in the host building. A "very early" smoke detection system continuously samples air in the test chamber and the test support enclosure and notifies a central lab-wide monitoring/dispatch station of any threshold is exceeded.



A high transparency perforated metal facing gives the wedges a bright and uniform appearance.

Flexible control room

The test chamber and adjacent test support enclosure are physically and acoustically separate structures located on either side of a 4in. air space filled with fiberglass insulation. For most test programs, the test support enclosure functions as a control room and houses acoustical data acquisition and customer test control equipment. The test support enclosure, therefore, is also a modular pre-fabricated panel room with 4in. thick wall and ceiling panels rated at STC 49. Silenced (rated at NC 25) and filtered (30 percent efficiency) two-speed ventilation and absorptive interior wall and ceiling panel surfaces provide the office-like environment appropriate for most operations.

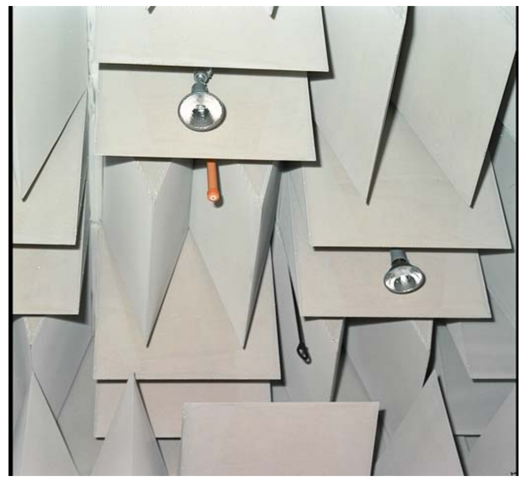
The test support enclosure ventilation system is separate from both the host building system and the stand-alone system that serves the test chamber.

For test programs where the test article requires remotely located support equipment whose noise emissions could contaminate the acoustical signals being measured in the test chamber, the test support enclosure functions as a noise control enclosure. In this case, the acoustical data acquisition and customer test control equipment and functions are relocated to the hallway outside the test support enclosure by means of rolling equipment carts and movable modular furnishings. Electrical receptacles on the exterior walls of both the chamber and test support enclosure facilitate easy reconfiguration of the test control and data acquisition setup.

The floor of the test support enclosure is located at grade in the host building, enabling equipment to be moved in and out easily through a set of 8ft.(wide) by 10ft. (high) double doors. Test support equipment located in the enclosure is powered by 120V AC or 208V three-phase electrical service supplied in the control room. In turn, this equipment provides services to the test article in the chamber via temporary customer-supplied hoses, cables and tubing that pass through silenced utility sleeves in the walls of the two rooms.

Utility sleeves in the other walls of the test support enclosure allow phone, Ethernet, compressed air and water services to be temporarily supplied to the test support enclosure from the host building and also allow data and test control functions to be routed, when required, to the alternate test control location in the adjacent hallway. Video and intercom systems facilitate remote test operation as well as communication between the chamber and other locations during setup and testing.

Personnel traffic between the test chamber and test support enclosure must pass through a series of two aligned doors, one in each of the rooms. A set of steps recessed into the floor wedge cart located immediately inside the chamber provides a means of navigating the 46in. change in elevation between the floor of the test support enclosure and the test chamber walking surface above the floor wedges.



Sampling ports for a “very early” smoke detection system provide a minimally invasive and acoustically invisible method of continuously sampling air in the test chamber and the test support enclosure.

Acoustic emission measurements

Automated data acquisition customization

The ATL provides a comprehensive array of acoustical testing services, including sound power level in accordance with precision and engineering grade standards. The acoustical data acquisition system is based on National Instruments' (NI) Sound Power System, which incorporates PC-based digital signal analysis hardware with LabVIEW-based software to automate system configuration, acoustical measurements, computations and reporting.

The SPS implements acoustical measurement procedures defined in several basic measurement standards with better performance, complete process documentation and less opportunity for error than traditional measurement systems. An automated routine performs calibration functions, acquires data and performs real-time 1/3-octave band and narrowband analysis and data corrections. At the conclusion of each test point the program automatically generates a certificate-style report as well as supporting documentation using Microsoft Excel templates that may be customized to meet the requirements of each test program.

Simultaneous multichannel customization

Some test articles require specialized services and utilities that mimic ISS interfaces (e.g., compressed gasses, cooling, exhaust, etc.) to demonstrate and verify acoustic emissions for all noise-generating operating conditions, per ISS acoustic emission requirements. Supplying all these interfaces in a laboratory environment is rarely cost effective and often technically challenging, so the practical operating time of some test articles is severely limited.

Nelson Acoustical Engineering of Texas, USA, developed a software Multi-Channel Enhancement (MCE) that augments SPS to allow simultaneous acquisition and real-time analysis of multiple channels of acoustical signals. The MCE expedites the verification testing process and facilitates identification of equipment noise sources and transmission paths by simplifying the testing process and increasing laboratory throughput.

Summary

Science experiment payloads developed for the International Space Station (ISS) are subject to acoustic noise emission requirements that support hearing conservation, speech communication and safety goals as well as the prevention of vibrations that could adversely impact research data. A key element in the successful design of low-noise space flight hardware is the frequent use of acoustical testing as a diagnostic and design verification tool. NASA Glenn Research Center has constructed an Acoustical Testing Laboratory (ATL), a 100Hz. vibration-isolated anechoic chamber with 27ft. by 23ft. by 20ft. (high) outside dimensions and removable floor wedges that allow the facility to be configured as either a hemi-anechoic or fully-anechoic chamber. As an in-house laboratory, the ATL provides an accessible, secure and flight-hardware-compatible acoustical testing environment that virtually ensures compliance with ISS hearing conservation goals by facilitating the successful implementation of low-noise payload design strategies early in the life of each project.

The test support enclosure houses test control and data acquisition functions and doubles as a noise control enclosure when testing articles that require remote connections to high-noise support equipment and services.